MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 3, 2021/2022**

## ETM3086 – MOBILE AND SATELLITE COMMUNICATIONS

(TE)

08 AUGUST 2022
9.00 A.M. – 11.00 A.M.
(2 Hours)

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**INSTRUCTION TO STUDENT**

1. This question paper consists of 8 pages (including this cover page) with 4 questions.
2. Attempt all **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given. The total marks are 100.
3. Please write all your answers in the Answer Booklet provided.

## Question 1

(a) A new cellular network is required to cover an area of 111 $km^2$. There are 2 proposals which are described as below:

Network A:19-cell cluster, Cell radius: 800m
Network B: 7-cell cluster, Cell radius: 800m

(i) For each network, find the number of clusters required to cover the whole area. (Assume hexagonal cell is used and area of one hexagonal cell is given as, $A = 2.598(D/2)^2$ where D is the diameter of a cell)

[5 marks]

(ii) By comparing these two networks, explain about the system capacity and transmission quality for each network.

[4 marks]

(b) Adjacent channels interference results from imperfect receiver filters which allow nearby frequencies to leak into the passband. The problem can be particularly serious in the presence of near-far effect.

(i) Describe a near-far effect situation.

[4 marks]

(ii) Explain one frequency assignment strategy to minimize the adjacent channel interference.

[2 marks]

(c) For a N = 7 system with GOS = 1% and average call length of two minutes, find the traffic capacity loss due to trunking for 57 channels when going from omni-directional antennas to 60° sectored antennas. (Assume that blocked calls are cleared and the average per user call rate is $\lambda = 1$ per hour).

[10 marks]

**Continued...**

## Question 2

(a) With the aid of diagrams, describe one type of propagation of radio frequency (RF) waves for each of the frequency bands below:

(i) Below 2 MHz

[3 marks]

(ii) 2 MHz to 30 MHz

[3 marks]

(iii) Above 30MHz

[3 marks]

(b) Small scale fading is caused by interference between two or more versions of the transmitted signals which arrive at the receiver at slightly different times and combine to give a resultant signal which can vary widely in amplitude and phase.

(i) Explain the 'coherence bandwidth' that is used to characterize the channel in the frequency domain.

[2 marks]

(ii) Describe the differences between flat fading and frequency selective fading.

[6 marks]

(c) A cellular operator, EXTEL, has installed a transmitter operating at carrier frequency of 1200 MHz. Given that you are in a vehicle moving on a motorway at a speed of 110 km per hour, evaluate the received carrier frequency if your vehicle is moving

(i) directly towards the transmitter.

[4 marks]

(ii) directly away from the transmitter.

[2 marks]

(iii) in a direction which is perpendicular to the direction of arrival of the transmitted signal.

[2 marks]

**Continued...**

## Question 3

(a) The earth rotates once in a sidereal day (23 hours 56 minutes 4.09 seconds), and a geostationary satellite must have exactly the same orbital period. Consider a satellite in a circular orbit in the equatorial plane with a period of 23 hours and 50 minutes. Find,

(i) The radius of the satellite orbit.

[3 marks]

(ii) The angular drift of the satellite around its orbit per sidereal day, measured at the earth center.

[2 marks]

(iii) The direction of the drift – towards the east or towards the west.

[2 marks]

(b) Johannes Kepler (1571-1630) derived empirically three laws describing planetary motion.

(i) With the aid of diagrams, explain the three laws.

[9 marks]

(ii) By using third Kepler's law, show that a geostationary satellite must have an altitude of about 35,800 km.

[5 marks]

(c) Explain the eclipse phenomena and its effect on satellite communications.

[4 marks]

**Continued...**

## Question 4

(a) Identify four common losses in a satellite link.

[4 marks]

(b) A link budget for a transparent satellite uplink is shown in **Table Q4** below.

**Table Q4**

| Path | Parameter | Unit | Value |
|---|---|---|---|
| Uplink Earth Station | HPA output power | dBW | 2.00 |
| | Feed loss | dB | 1.05 |
| | Antenna gain | dBi | 41.0 |
| | Pointing loss | dB | 0.20 |
| | | | |
| Uplink path | Uplink frequency | GHz | 6.0 |
| | Uplink range | km | 38000 |
| | Uplink rain attenuation | dB | 2.68 |
| | | | |
| Satellite | Satellite saturated power flux density (SFD) | $dBW/m^2$ | -84.56 |
| | Satellite antenna gain to noise temperature ratio (G/T) | dB/K | -0.15 |
| | | | |
| | Uplink Carrier to cross-polarization interference ratio (C/XPD) | dB | 27.31 |
| | Uplink Carrier to adjacent satellite interference ratio (C/Adj) | dB | 37.32 |

If the noise bandwidth is 105 kHz, compute:

(i) The earth station transmitted EIRP in dBW.

[2 marks]

(ii) The uplink (free space) spreading loss in dB.

[3 marks]

(iii) The received power flux density by the satellite in $dBW/m^2$.

[3 marks]

(iv) The satellite input back-off in dB.

[2 marks]

(v) The uplink carrier-to-thermal noise ratio $(C/N)_{thermal}$ in dB.

[8 marks]

(vi) The total uplink carrier-to-noise ratio (C/N) in dB.

[3 marks]

**Continued...**

## Appendix I: Constant values

| | | |
|---|---|---|
| Gravitation parameter, $\mu$ | = | $3.986\times10^{14}$ m$^3$/s$^2$ |
| Mean Earth radius, $R_E$ | = | 6378 km |
| Speed of light, $c$ | = | $3\times10^{8}$ m/s |
| Sidereal day | = | 23h 56m 4.09s |
| Boltzmann constant, $k$ | = | $1.379\times10^{-23}$ J/K = -228.6 dBW/Hz K |

## Appendix II: Table of Complementary Error Function

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_z^\infty e^{-t^2}dt \quad \text{for } 0\le z\le 3.99 \text{ in steps of } 0.01$$

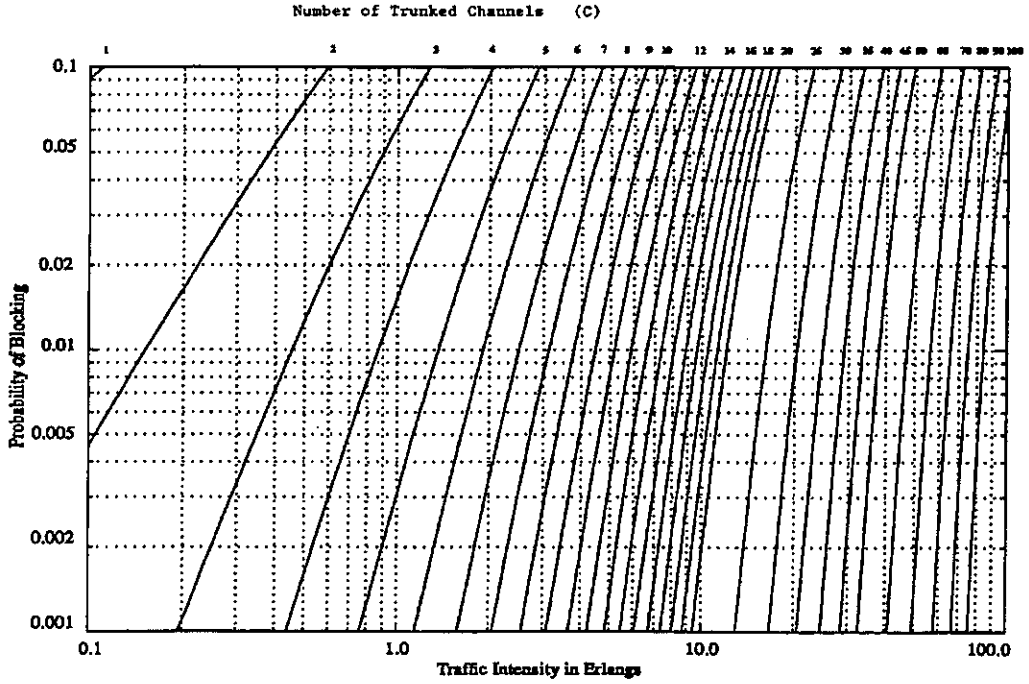
| z | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.000E+00 | 9.887E-01 | 9.774E-01 | 9.662E-01 | 9.549E-01 | 9.436E-01 | 9.324E-01 | 9.211E-01 | 9.099E-01 | 8.987E-01 |
| 0.1 | 8.875E-01 | 8.764E-01 | 8.652E-01 | 8.541E-01 | 8.431E-01 | 8.320E-01 | 8.210E-01 | 8.100E-01 | 7.991E-01 | 7.882E-01 |
| 0.2 | 7.773E-01 | 7.665E-01 | 7.557E-01 | 7.450E-01 | 7.343E-01 | 7.237E-01 | 7.131E-01 | 7.026E-01 | 6.921E-01 | 6.817E-01 |
| 0.3 | 6.714E-01 | 6.611E-01 | 6.509E-01 | 6.407E-01 | 6.306E-01 | 6.206E-01 | 6.107E-01 | 6.008E-01 | 5.910E-01 | 5.813E-01 |
| 0.4 | 5.716E-01 | 5.620E-01 | 5.525E-01 | 5.431E-01 | 5.338E-01 | 5.245E-01 | 5.153E-01 | 5.063E-01 | 4.973E-01 | 4.883E-01 |
| 0.5 | 4.795E-01 | 4.708E-01 | 4.621E-01 | 4.535E-01 | 4.451E-01 | 4.367E-01 | 4.284E-01 | 4.202E-01 | 4.121E-01 | 4.041E-01 |
| 0.6 | 3.961E-01 | 3.883E-01 | 3.806E-01 | 3.730E-01 | 3.654E-01 | 3.580E-01 | 3.506E-01 | 3.434E-01 | 3.362E-01 | 3.292E-01 |
| 0.7 | 3.222E-01 | 3.153E-01 | 3.086E-01 | 3.019E-01 | 2.953E-01 | 2.888E-01 | 2.825E-01 | 2.762E-01 | 2.700E-01 | 2.639E-01 |
| 0.8 | 2.579E-01 | 2.520E-01 | 2.462E-01 | 2.405E-01 | 2.349E-01 | 2.293E-01 | 2.239E-01 | 2.186E-01 | 2.133E-01 | 2.082E-01 |
| 0.9 | 2.031E-01 | 1.981E-01 | 1.932E-01 | 1.884E-01 | 1.837E-01 | 1.791E-01 | 1.746E-01 | 1.701E-01 | 1.658E-01 | 1.615E-01 |
| 1.0 | 1.573E-01 | 1.532E-01 | 1.492E-01 | 1.452E-01 | 1.414E-01 | 1.376E-01 | 1.339E-01 | 1.302E-01 | 1.267E-01 | 1.232E-01 |
| 1.1 | 1.198E-01 | 1.165E-01 | 1.132E-01 | 1.100E-01 | 1.069E-01 | 1.039E-01 | 1.009E-01 | 9.800E-02 | 9.516E-02 | 9.239E-02 |
| 1.2 | 8.969E-02 | 8.704E-02 | 8.447E-02 | 8.195E-02 | 7.949E-02 | 7.710E-02 | 7.476E-02 | 7.249E-02 | 7.027E-02 | 6.810E-02 |
| 1.3 | 6.599E-02 | 6.394E-02 | 6.193E-02 | 5.998E-02 | 5.809E-02 | 5.624E-02 | 5.444E-02 | 5.269E-02 | 5.098E-02 | 4.933E-02 |
| 1.4 | 4.771E-02 | 4.615E-02 | 4.462E-02 | 4.314E-02 | 4.170E-02 | 4.030E-02 | 3.895E-02 | 3.763E-02 | 3.635E-02 | 3.510E-02 |
| 1.5 | 3.389E-02 | 3.272E-02 | 3.159E-02 | 3.048E-02 | 2.941E-02 | 2.838E-02 | 2.737E-02 | 2.640E-02 | 2.545E-02 | 2.454E-02 |
| 1.6 | 2.365E-02 | 2.279E-02 | 2.196E-02 | 2.116E-02 | 2.038E-02 | 1.962E-02 | 1.890E-02 | 1.819E-02 | 1.751E-02 | 1.685E-02 |
| 1.7 | 1.621E-02 | 1.559E-02 | 1.500E-02 | 1.442E-02 | 1.387E-02 | 1.333E-02 | 1.281E-02 | 1.231E-02 | 1.183E-02 | 1.136E-02 |
| 1.8 | 1.091E-02 | 1.048E-02 | 1.006E-02 | 9.653E-03 | 9.264E-03 | 8.889E-03 | 8.528E-03 | 8.179E-03 | 7.844E-03 | 7.521E-03 |
| 1.9 | 7.210E-03 | 6.910E-03 | 6.622E-03 | 6.344E-03 | 6.077E-03 | 5.821E-03 | 5.574E-03 | 5.336E-03 | 5.108E-03 | 4.889E-03 |
| 2.0 | 4.678E-03 | 4.475E-03 | 4.281E-03 | 4.094E-03 | 3.914E-03 | 3.742E-03 | 3.577E-03 | 3.418E-03 | 3.266E-03 | 3.120E-03 |
| 2.1 | 2.979E-03 | 2.845E-03 | 2.716E-03 | 2.593E-03 | 2.475E-03 | 2.361E-03 | 2.253E-03 | 2.149E-03 | 2.049E-03 | 1.954E-03 |
| 2.2 | 1.863E-03 | 1.776E-03 | 1.692E-03 | 1.612E-03 | 1.536E-03 | 1.463E-03 | 1.393E-03 | 1.326E-03 | 1.262E-03 | 1.201E-03 |
| 2.3 | 1.143E-03 | 1.088E-03 | 1.034E-03 | 9.838E-04 | 9.354E-04 | 8.893E-04 | 8.452E-04 | 8.032E-04 | 7.631E-04 | 7.249E-04 |
| 2.4 | 6.885E-04 | 6.538E-04 | 6.207E-04 | 5.892E-04 | 5.592E-04 | 5.306E-04 | 5.034E-04 | 4.774E-04 | 4.528E-04 | 4.293E-04 |
| 2.5 | 4.070E-04 | 3.857E-04 | 3.655E-04 | 3.463E-04 | 3.280E-04 | 3.107E-04 | 2.942E-04 | 2.785E-04 | 2.636E-04 | 2.495E-04 |
| 2.6 | 2.360E-04 | 2.233E-04 | 2.112E-04 | 1.997E-04 | 1.888E-04 | 1.785E-04 | 1.687E-04 | 1.594E-04 | 1.506E-04 | 1.422E-04 |
| 2.7 | 1.343E-04 | 1.268E-04 | 1.197E-04 | 1.130E-04 | 1.066E-04 | 1.006E-04 | 9.492E-05 | 8.952E-05 | 8.441E-05 | 7.958E-05 |
| 2.8 | 7.501E-05 | 7.069E-05 | 6.661E-05 | 6.275E-05 | 5.910E-05 | 5.566E-05 | 5.240E-05 | 4.933E-05 | 4.642E-05 | 4.368E-05 |
| 2.9 | 4.110E-05 | 3.866E-05 | 3.635E-05 | 3.418E-05 | 3.213E-05 | 3.020E-05 | 2.838E-05 | 2.667E-05 | 2.505E-05 | 2.353E-05 |
| 3.0 | 2.209E-05 | 2.074E-05 | 1.947E-05 | 1.827E-05 | 1.714E-05 | 1.608E-05 | 1.508E-05 | 1.414E-05 | 1.326E-05 | 1.243E-05 |
| 3.1 | 1.165E-05 | 1.092E-05 | 1.023E-05 | 9.578E-06 | 8.970E-06 | 8.398E-06 | 7.862E-06 | 7.358E-06 | 6.885E-06 | 6.442E-06 |
| 3.2 | 6.026E-06 | 5.635E-06 | 5.269E-06 | 4.926E-06 | 4.604E-06 | 4.303E-06 | 4.020E-06 | 3.755E-06 | 3.507E-06 | 3.275E-06 |
| 3.3 | 3.058E-06 | 2.854E-06 | 2.664E-06 | 2.485E-06 | 2.319E-06 | 2.162E-06 | 2.017E-06 | 1.880E-06 | 1.753E-06 | 1.633E-06 |
| 3.4 | 1.522E-06 | 1.418E-06 | 1.321E-06 | 1.230E-06 | 1.145E-06 | 1.066E-06 | 9.922E-07 | 9.233E-07 | 8.590E-07 | 7.990E-07 |
| 3.5 | 7.431E-07 | 6.910E-07 | 6.423E-07 | 5.970E-07 | 5.548E-07 | 5.155E-07 | 4.788E-07 | 4.447E-07 | 4.130E-07 | 3.834E-07 |
| 3.6 | 3.559E-07 | 3.303E-07 | 3.064E-07 | 2.843E-07 | 2.636E-07 | 2.445E-07 | 2.267E-07 | 2.101E-07 | 1.947E-07 | 1.804E-07 |
| 3.7 | 1.672E-07 | 1.548E-07 | 1.434E-07 | 1.327E-07 | 1.229E-07 | 1.137E-07 | 1.052E-07 | 9.736E-08 | 9.005E-08 | 8.328E-08 |
| 3.8 | 7.700E-08 | 7.119E-08 | 6.579E-08 | 6.080E-08 | 5.617E-08 | 5.189E-08 | 4.792E-08 | 4.425E-08 | 4.085E-08 | 3.770E-08 |
| 3.9 | 3.479E-08 | 3.210E-08 | 2.961E-08 | 2.731E-08 | 2.518E-08 | 2.322E-08 | 2.140E-08 | 1.972E-08 | 1.817E-08 | 1.674E-08 |

Note: 1.000E-01 = $1.000 \times 10^{-1}$

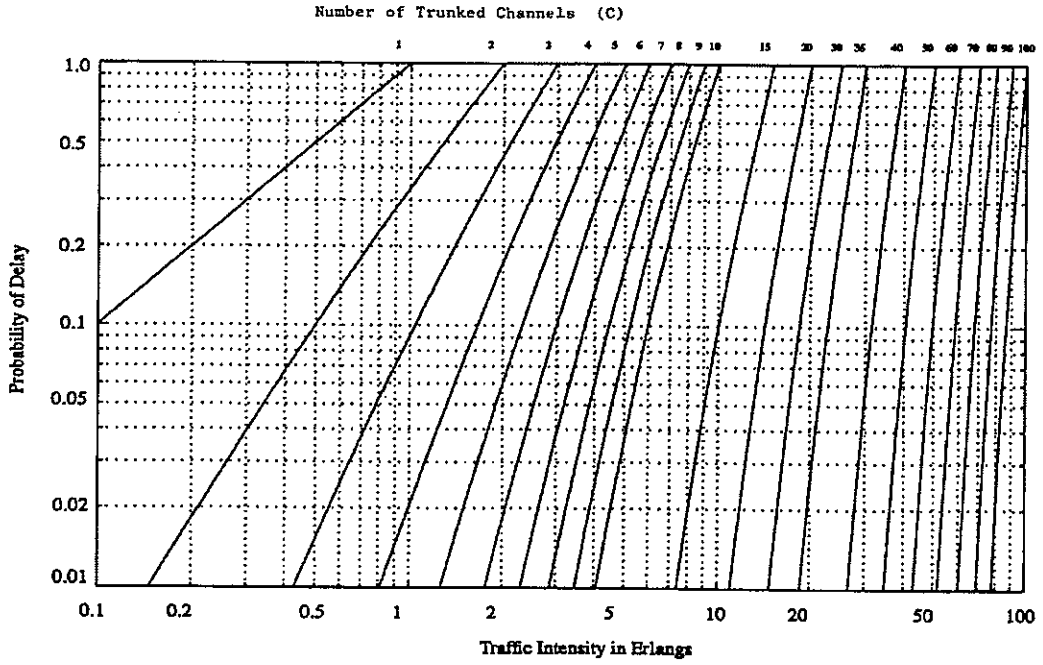
For $z > 4$, $\quad erfc(z)\approx\frac{1}{\sqrt{\pi}}\left(\frac{e^{-z^2}}{z}\right)$

**Continued...**

## Appendix III: Erlang B and Erlang C Chart




The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.




The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

**Continued...**

## Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

**Antenna**

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter $D$:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right) A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

**Link Analysis**

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss, $L_{FS} = \left(\dfrac{4\pi R}{\lambda}\right)^2$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

**FDM-FM-FDMA Satellite System**

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

where $\log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$

Relationship between $C/N$ and $S/N$ is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

**End of Paper**